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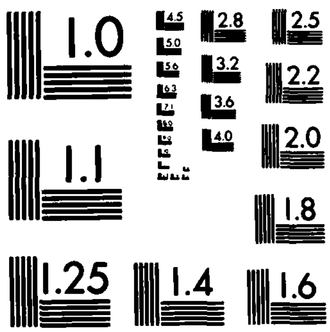

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DEPARTMENT OF DEFENCE SUPPORT

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORIES

MELBOURNE, VICTORIA

Aerodynamics Technical Memorandum 341

PROGRAMS FOR THE TRANSONIC WIND TUNNEL DATA PROCESSING INSTALLATION PART 10: 6 COMPONENT MEASUREMENTS UPDATED

J.B. WILLIS

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PROGRAMS FOR THE TRANSONIC WIND TUNNEL DATA PROCESSING INSTALLATION PART 10: 6 COMPONENT MEASUREMENTS UPDATED

by

J. B. WILLIS

SUMMARY

This memorandum describes the current version of the program used for 6 component measurements using strain gauge balances and the PDP8/I installation in the Transonic Wind Tunnel. The program is an updated version of ARL Tech. Memo. A264[1] and has been in use for several years. Changes to the original program include on-line display, model weight correction, and operation with the Pollock strain gauge equipment[2]. Although the 8/I is scheduled for replacement, it may be some time before the change-over to a new installation can occur. Also, some of the program detail may be useful to the new arrangement.

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CONTENTS

1. INTRODUCTION

This memorandum describes the program 6END used for 6 component force and moment measurements in the Transonic Wind Tunnel, and it is intended primarily for operators of this wind tunnel. The program is for use with strain gauge balances using first order balance interactions. When written, the 8/I installation consisted of:

> DEC PDP 8/I with extended arithmatic and 12K of core, Plotter line printer LP3000, Tektronix Type 611 storage display and Tektronix C10 Polaroid Camera, Calcomp Plotter Type 565, 2 minidiscs type DF32, 2 DEC tape transports, multiplexer, and ASR33 teletype. This has some time ago, changed to include 24K of core, ASR43 teletype, high speed paper tape reader, dual floppy discs, and one RK05 disc. However, the original machine dates back to 1968, and is nearing the end of its life, and installation is scheduled for replacement in the near future. Nevertheless, it could be several years before change-over occurs, and meantime the present operating program will be used. Further, some of the thought behind the program to be discussed here may be useful in future programs.

The program 6END has evolved over many years of tunnel operation, and has been continually modified in accordance with tunnel staff wishes. Operating experience showed that it is faster and more convenient to function using only the display without the plotter, so this program does not plot on-line; instead, off-line plotting and cross-plotting programs were developed, and are now separate programs. Model weight corrections have been incorporated, and the program changed to suit the output from the strain gauge equipment. The program has been in use for many years and has been modified from time to time in response to users recommendations. Listings are not included, since the program occupies 3 fields and is too big to include here.

2. PROGRAM OPERATION

Tables must be compiled as in Fig. 1 (see Refs. 4, 5 and section 4), keeping in mind that the final print out limits coefficients, including $C_L{}^2$, to a maximum of 99. Tables should be stored on disc as on ASCII file TABS, and all signs and digits should be entered, even if zero, and the decimal point is shown by the dotted line in Fig. 1 and should not be entered. Tabs, carriage returns and text may be entered, but will not be saved for future print out. It is good practice to store the disc file on DEC tape so that it can be restored to the disc if lost from there.

The program uses the top disc for data storage and will check to see that the top disc is clear, and will print out files on the top disc, but it is more efficient to clear the two discs of all file except POP, PIP, .SYM, TABS, DET (or EDIT) and the undeletable .CD and LOAD. Using PIP, transfer 6END, 6ØI1, 6ØI2, 61I1, 62I1, and print out of disc should be :

```
FB=0463

NAME  TYPE    BLK

8G
POP .SYS (1) 0004
PIP .SYS (0) 0025
LOAD.SYS (0) 0003
.CD..SYS (0) 0006
.SYM.SYS (0) 0017
DET .SYS (0) 0025
60I1.SYS (0) 0010
6END.SYS (0) 0037
6012.SYS (0) 0013
61I1.SYS (1) 0034
62I1.SYS (2) 0040
TABS.ASCII   0003

*OPT-
```

The only variation permitted is that the number of blocks for TABS may vary, and affect the quoted number of free blocks.

With the computer running in MONITOR, type 6END, carriage return, and the program will load and stop, having found and loaded from disc 6ØI1 and 62I1 (At the end of the ident and tables bit, it loads 6ØI2 and 61I1). There are long pauses while these loadings occur. It is good practice to type 6END, and when it stops, turn on all auxiliaries, set JOB and IDENT, check DEC tapes etc. Then start the program at *201. The program loads 6ØI1 and 62I1 and then checks that the top disc has been cleared. If not, DISC 2 NOT CLEAR, followed by the names of the offending files are typed out on the teletype and the program returns to MONITOR to allow the top disc to be cleared.

If interface power has not been turned on "NO POWER" appears on the teletype. Turn on the power and the program proceeds normally, typing DECTAPE?

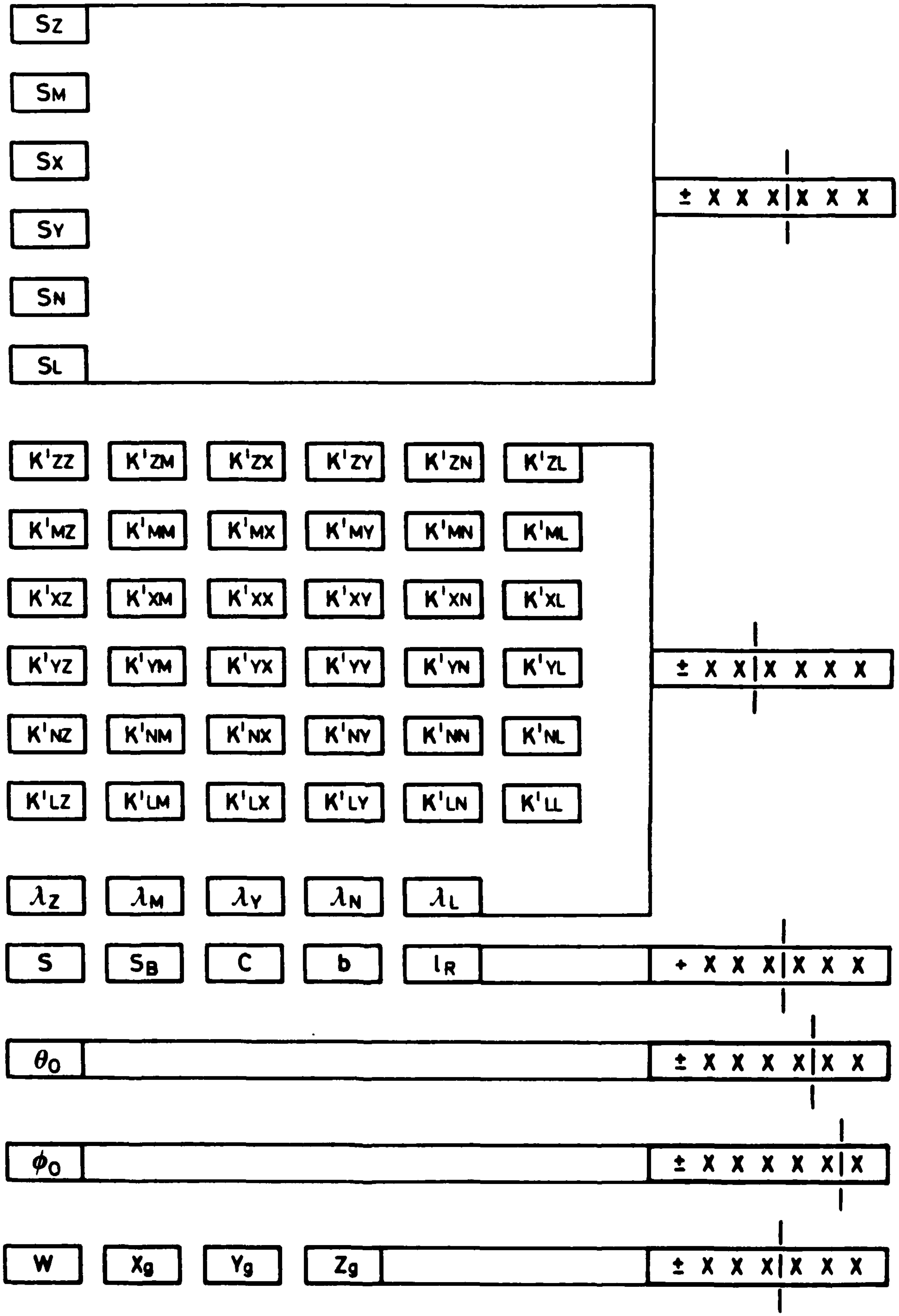

SZ
SM
SX
SY
SN
SL
± X X X|X X X
K'ZZ K'ZM K'ZX K'ZY K'ZN K'ZL
K'MZ K'MM K'MX K'MY K'MN K'ML
K'XZ K'XM K'XX K'XY K'XN K'XL
K'YZ K'YM K'YX K'YY K'YN K'YL
K'NZ K'NM K'NX K'NY K'NN K'NL
K'LZ K'LM K'LX K'LY K'LN K'LL
λZ λM λY λN λL
± X X|X X X X
S SB C b lR
+ X X X|X X X
θO
± X X X X|X X
φO
± X X X X X|X
W Xg Yg Zg
± X X X|X X X

FIG.1 TABLES

The question is whether the operator wants to store the ident block and tables on DEC tape or not. For verification of tables or a repeat run, or for preliminary running, DEC tape may not be required.

Type Y for Yes, N for No (no CR required). If Yes, FIRST BLOCK No = Ø Ø Ø Ø.

CORRECT? will appear and requires Y or N as before. If No, FIRST BLOCK No = appears, and requires 4 digits followed by C.R. If a mistake in typing is made, type RUBOUT and go around again. JOB NO = NN and IDENT NO = NNN will now be typed out on the teletype, followed by DATE which requires NN for day NN for month NN for year, and the program inserts spaces between. OPERATOR will accept up to 8 letters followed by CR DETAILS next appears and still expects about 72 characters per line and 2 lines maximum - i.e. unchanged from ASR33. A C.R. is required to terminate each line, and 2 C.R.'s in all must be typed for the program to proceed, even if the record line is not used for text.

It is essential that details of the test be included here, when tunnel running begins, and that it be stored on DEC tape. This is the only means, at a later date, of identifying the data that follows on the DEC tape. Thus, on the first pass of the program when proper data are expected to be recorded, sufficient details must be included to identify the test precisely. Configuration details should be included and enough information provided so that later other users can accurately identify the data - otherwise, the DEC tape shows a lot of data that, in time, may be meaningless. Later passes of the program should use the "Details" section to record more exact details of the data to follow. In all tests, the improtance of the "Details" cannot be overemphasized.

By now, the line printer has printed out

JOB NO = NN   IDENT NO = NNN   Date: NN NN NN
OPERATOR: ABC
DETAILS: The Text typed in.

The tables are now looked for as "TABS" on the discs, and if this file is not found, the program expects the tables from paper tape and will wait. If TABS is found, or paper tape fed in, the tables are read into Field 1, printed on the printer, converted to binary and stored on Field 2 starting at *201. The identification block and the tables are now stored on DEC tape, using 4 DEC tape blocks for the ident segment and 6 blocks for the tables, a total of 10(10) blocks, provided DEC tape has been requested previously.

If DEC tape 2 is not set to REMOTE, or WRITE ENABLED, or a fault occurs, "DECTAPE ERROR" will appear on the teletype, and there is no recourse but to start again. The program now loads 6ØI2 from the disc into core as an overlay into Field Ø. Field 1 previously used in storing tables as read from disc, is now loaded with 61I1 and the teletype bell rings to indicate that this has been achieved. The program now goes to *1001 or Field Ø.

As before DECTAPE? appears and if Y, FIRST BLOCK No = NNNN CORRECT?

and so on exactly as before. However, the block number should be correct, unless the whole program has been reloaded. The DEC tape query here simply allows the operator the choice of doing a preliminary run with full print out but no DEC tape storage and is useful for checking out tables etc.

The program now checks to see if the display is turned on, and if so goes to Field I. If desired, typing W will cause the display grid to be drawn, and scales adjusted and moved (see section 3). The program now waits, apart from its normal computing and displaying Mach number on the control desk, until the "Record" push button is pressed, and the first reading must be initial zero. While more than one set of initial zeros may be taken, they are all printed out and stored on DEC tape, which tends to confuse other programs used to operate on the data later on. The present program simply overwrites initial zeros and ignores earlier ones, and is unaffected.

When the "Record" P.B. is pressed to take a non-zero set of data the display will automatically write. All display operations are now permitted until the final zeros are taken. Only one set of final zeros is possible as the program goes off to compute all the data, using mean zeros, and prints it out, stores it on DEC tape, stores it on the discs, and cycles back ready for the next set of data. Test block number is printed out to help locate the data. At present, no use is made of the final data stored on the discs. However, with increased storage capacity, this facility could be used to retain data for several configurations, and then make quick comparisons using the display. Such programming must wait until increased storage is available.

It should be pointed out that it is legitimate to restart the program at *1001, Field Ø, unless the program has been destroyed by some means. This allows the tables and ident part of the program to be ignored, and the tunnel data part of the program to be run. Therefore, if for some reason a tunnel run is regarded as suspect, the DEC tape block number can be set to the right value, and a new run carried out.

3. DISPLAY OPERATION

3.1 Mode

Normal mode of operation is "Record" mode, and this is the mode automatically entered by the program. Raw data are printed out and stored on DEC tape.

"Look" mode is provided, and here no raw data are printed or written on DEC tape. This mode is provided so that the tunnel operator can determine the shape of the curves and decide how many and where data points are needed. For this purpose, the tunnel may simply be accelerated through the required Mach number range with the operator pressing the "Record" first button as needed without bothering to obtain precise Mach numbers. Similarly, at constant Mach number, the model angle of attack may be continuously varied through the required range and the shape of the curves defined by the points taken.

Type CTRL R for Record Mode.
CTRL L for Look Mode.

It is permissible to change from one to the other as needed, and will be expected by the program any time after initial zeros and before final zeros.

3.2 Select Abscissa

Type V A then W to display coefficients versus α.
Type V B then W to display coefficients versus β.
Type V M then W to display coefficients versus Mach number.

The program loads in the V M state. It is permissible to go from one to another and back again.

3.3 Write Instruction

Type W. This will renew the display, or write the new one requested in (2) above.

3.4 Deletions

$$\text{Type}\ \left.\begin{array}{l}\text{L}\\ \text{M}\\ \text{C}\\ \text{D}\\ \text{N}\\ \text{1}\end{array}\right\}\ \text{followed by W.}$$

The coefficient typed is deleted from then on, and this is useful in giving a much clearer picture if only one or two coefficients are of interest.

Type 6 (W not required) to restores all 6 coefficients.

3.5 ZOOM

Type A+ Magnify abscissa
A- Diminish abscissa
A= Restore to original

O+ Magnify ordinate
O- Diminish ordinate
O= Restore to original.

Overflow out the ends does not occur - attempts to over-expand or overcompress are ignored.

Available scales are :

ABSCISSA	Increment per Grid Line on Display						
MACH NO.	0.2		0.1		0.05		0.02
ALPHA (DEG.)	10		5		2		1
BETA (DEG.)	10		5		2		1
	A =	A+ → ← A-		A+ → ← A-		A+ → ← A-	

ORDINATE	Imcrement per Grid Line on Display										
COEFFICIENTS (ALL)	1.0		0.4		0.2		0.1		0.05		0.02
	0 =	0+ → ← 0-		0+ → ← 0-		0+ → ← 0-		0+ → ← 0-		0+ → ← 0-	

3.6 Moving

Type ↑	to move up.
Type !	to move down.
Type >	to move right.
Type <	to move left.
Type RUBOUT	to centre both.

Each time one of these is typed, the display is moved by one grid line on the display, whatever that is at the time of moving. It is thus faster to move the display first and then expand, then the other way round.

Initial scales are :

M:# 0.4 to 1.4 in increments per grid line of 0.2.

α:# 0 to 60 deg. in increments per grid line of 10 deg.

β:# 0 to 60 deg. in increments per grid line of 10 deg.

Coefficients:- -4 to +4 in increments per grid line of 1.

During moving or zooming points may be lost from the display. Such points are never truly lost and will reappear when the display is suitably moved or scaled. (In part, the display has a visible window in a larger storage area and program protection takes over if the larger area is exceeded).

It is also quite possible to get a mixture of zooming and moving such that it becomes most confusing to operate further and in such cases it is frequently quicker to type VMW (or similar) and start over from the beginning.

3.7 X1 or X10 Facility

When the display is operated, it will be seen that some coefficients are plotted X10. Any coefficient may be displayed X1 or X10 by changing the contexts of locations #3000 to #3005 on Field 1. Ø in these locations produces X10, 7777 produces X1. Locations are :

#3000 L	3003 C
3001 M	3004 N
3002 D	3005 1

To do this, after the Field 1 program has been loaded and before taking initial zeros, stop the PDP8/I. Toggle the required values in to the appropriate locations and restart at #1001 or Field Ø.

This program change will be lost if the program is run from the beginning again, and to avoid frequent toggling it is better to SAVE the toggled program as 61I1.

3.8 Restrictions

Pressing the "Record" P.B. causes data to be written on the discs, operating the display requires data to be read from the discs. Efforts to provide protection have not been successful, and it is therefore best not to push the P.B. while the display is writing or use the teletype to issue display instructions while the recording program, which includes redrawing the display, is proceeding. In practice, this is no hardship as the operator normally presses the button to get his reading and then looks at the display, makes any changes needed to this, and then takes the next reading.

As at present programmed, as soon as final zeros are recorded, the display becomes inoperative. Although the actual picture remains, the program will not listen to the teletype because the program has gone on and is ready for the next run. Consequently, if the display is to be photographed, the display must be set up to the form needed before taking final zeros.

3.9 Photographing the Display

A Polaroid camera is available to take photographs of the display, and gives a print 1/2 full size. Remove both lens caps, press camera against screen, and press shutter and follow the Polaroid directions is all that is normally required. However, the screen blanks off for a short time every 90 seconds approximately, and so, if possible type W just before taking the photo, or if this is not possible, wait till the display comes on after blanking out, and then photograph.

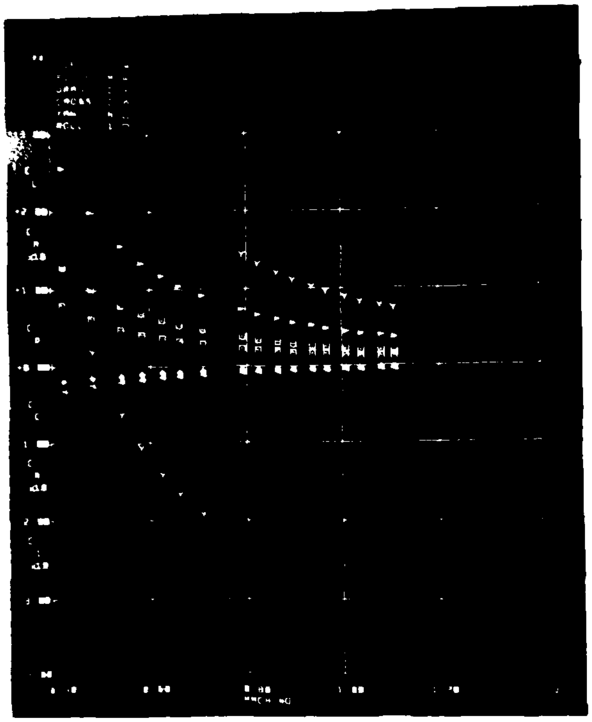
3.10 Malfunction

Every so often, about once in 2 or 3 days, the display will draw only part of the picture, and the program locks up. Press "ERASE" and the program will continue. The fault appears to be a hardware fault in the interrupt circuitry, but is too intermittent to make fault finding practical.

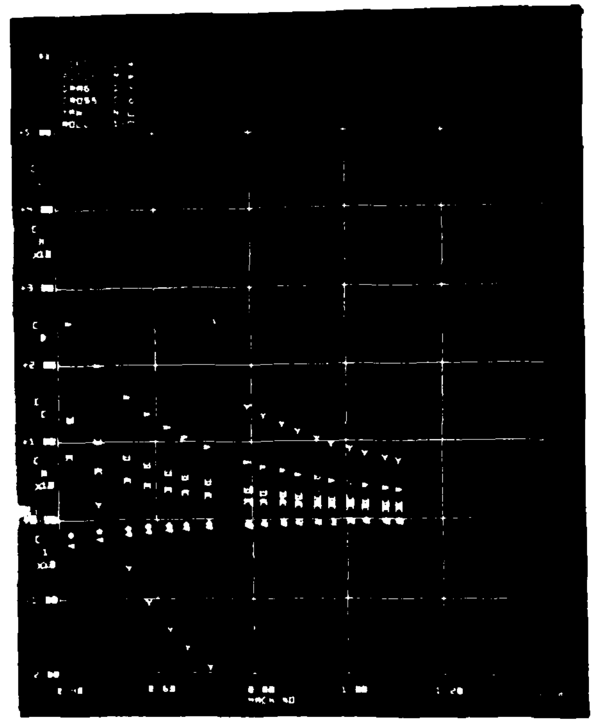
4. DESCRIPTION OF PROGRAM

4.1 General

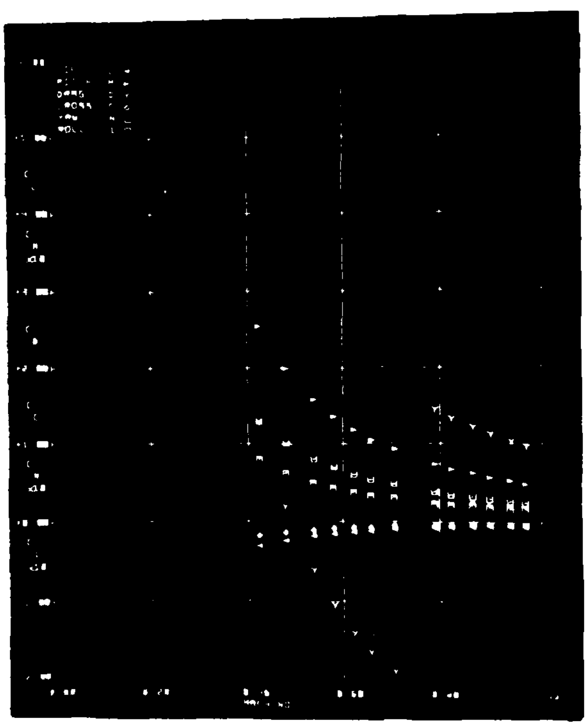
This program, 6END, occupies all fields and field Ø uses one overlay. Terminology used for the component parts of the program is :



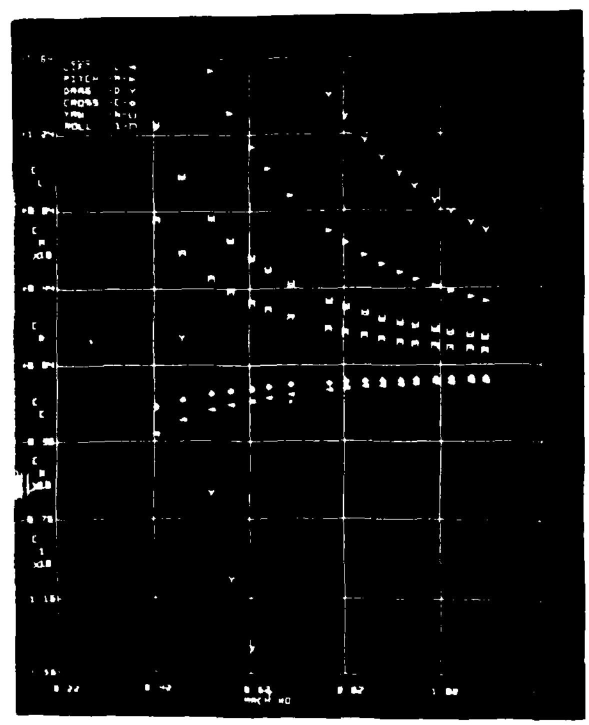
TYPICAL DISPLAY



MOVED DOWN

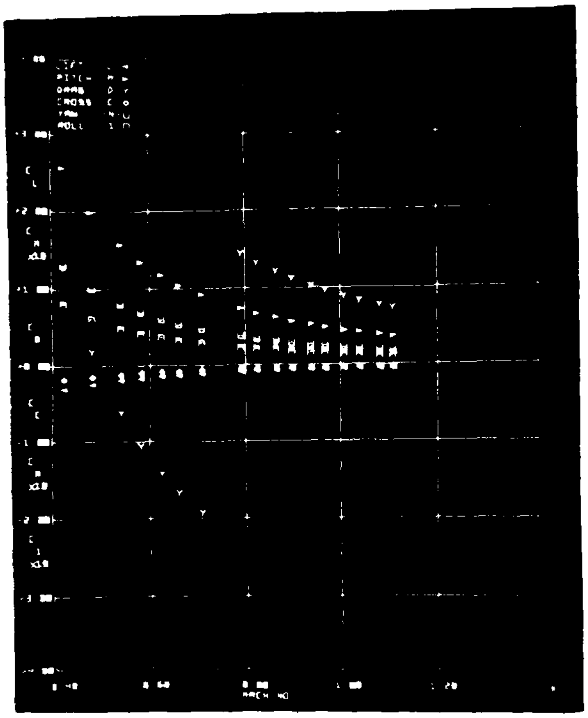


MOVED RIGHT

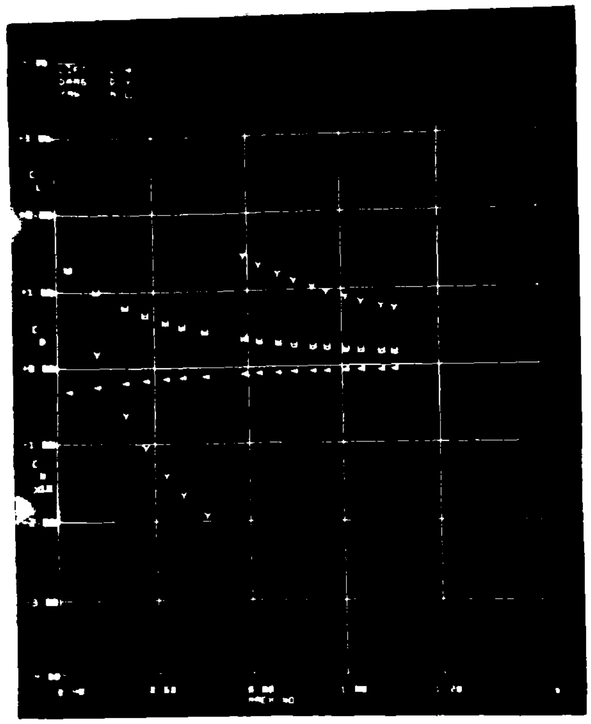


MOVED AND EXPANDED

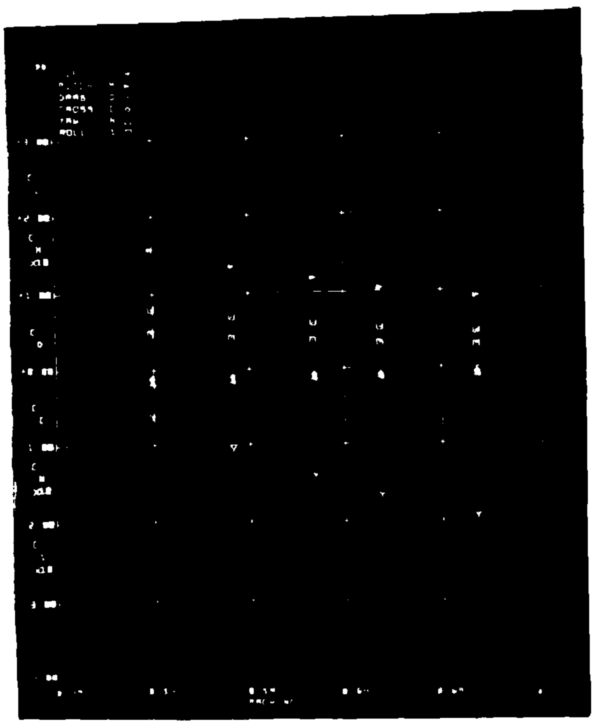
FIG.2 TYPICAL DISPLAY PHOTOGRAPHS ACTUAL SIZE.
SCREEN SIZE IS TWICE THIS SIZE.
PLOTTING AGAINST MACH NUMBER.



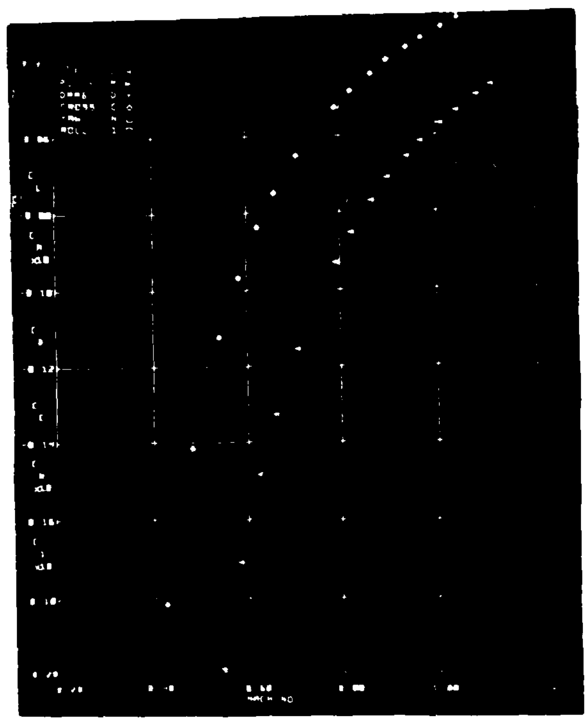
TYPICAL DISPLAY



THREE COMPONENTS DELETED

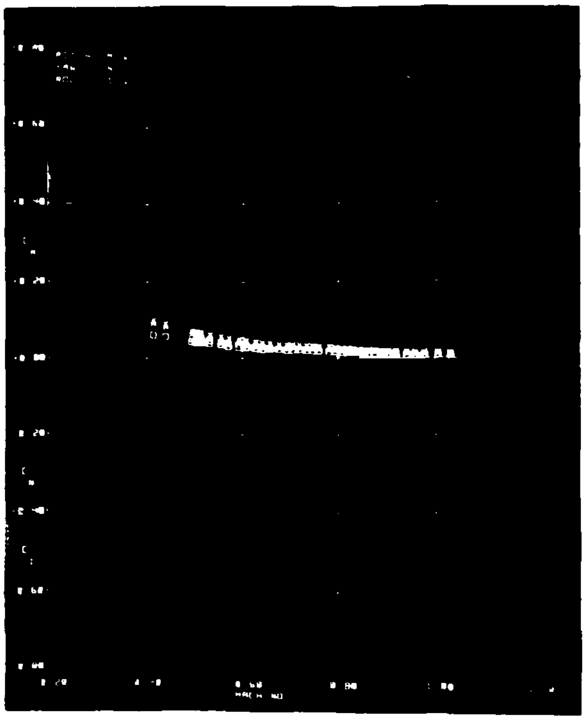


MACH NO. EXPANDED

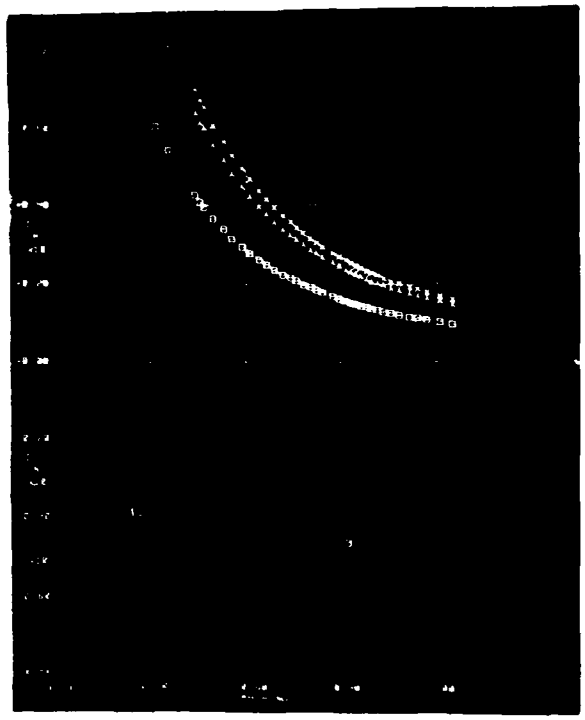


COEFFICIENTS EXPANDED

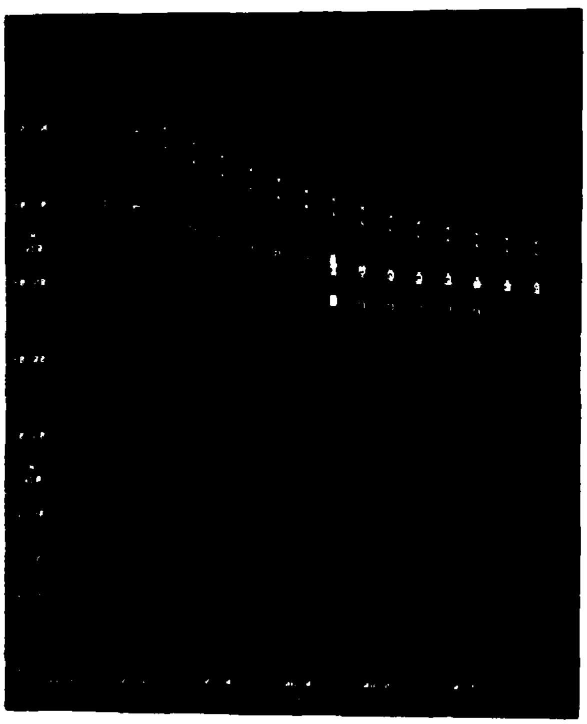
FIG. [illegible] TYPICAL DISPLAY PHOTOGRAPHS ACTUAL SIZE.
SCREEN SIZE IS TWICE THIS SIZE.
PLOTTED AGAINST MACH NUMBER.



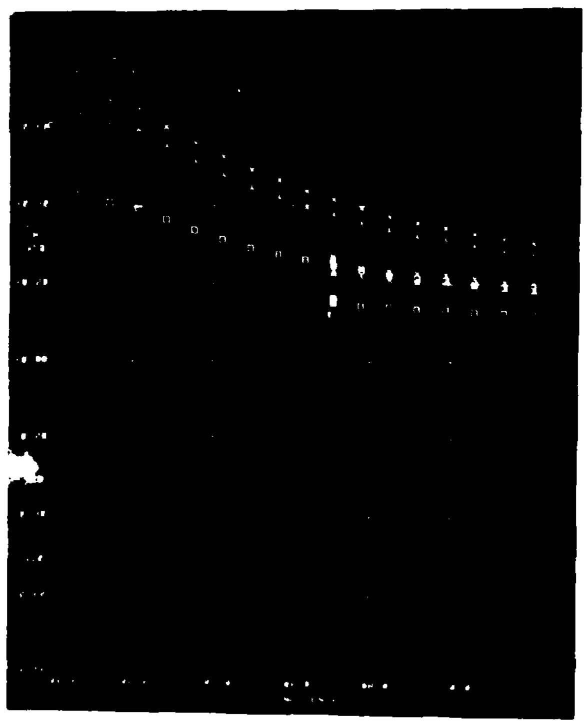
COEFFICIENTS XI



SAME COEFFICIENTS XIC



PLOTTING AGAINST BETA



PLOTTING AGAINST ALPHA

FIG. 2.1 TYPICAL DISPLAY PHOTOGRAPHS [illegible] SIZE.
[illegible] SIZE IS TWICE [illegible].
PLOT [illegible] EACH [illegible], [illegible] ALPHA.

6 for 6 six component program

N_1 for field

I for insert

N_2 for number of the insert.

Thus field 2 is 62I1, field 1 is 61I1, and field Ø uses 6ØI1 and 6ØI2. After 6END is loaded, the program is self loading, and it is therefore easy to add future inserts or overlays as needed. Thus 61I2 could be a plot program to overlay the display program and provide plotted data at the end of the tunnel run.

6END, the first part of the program loaded, contains the subroutine section[3] which is common to most tunnel running programs, and is therefore kept as a separate entity. It contains B.C.D. to binary, binary to B.C.D., basic multiply and divide, Reynolds number and Mach number subroutines. These are largely the same as in Ref. 3. All are obvious except the Mach number subroutine and its operation. Wherever 6END is running and the interrupt is turned ON, it is interrupted about twice a second by pulses from an electronic clock. When this interrupt occurs, tunnel static and total pressure which are continuously measured by automatic manometers, are read in, Mach number computed and then displayed on the tunnel control desk. Thus, all the time 6END is performing other functions, it is still producing tunnel Mach number for the plant operator.

In this connection it should be noted that 6END, which uses the same Mach number subroutine, computes M^2 and uses this to compute coefficients. The Mach number printed out by the program should not be squared - it is much more accurate to get M^2 from static and total pressure - for any further computations.

These subroutines occupy, on Field Ø, *50-*75, *106-*131, *6244-*7551, the page Ø locations being used for addressing the subroutines.

The Identification section is much the same as before, but tables must now be in the form shown in Fig. 1, and are expected to be on disc as on ASC11 file TABS. To eliminate the weight correction terms, zeros should be entered, and to operate with less than 6 components, the strain gauge balance tables should contain zeros in the appropriate places. To produce the inverse balance parameters matrix see Refs. 4 and 5. The Identification section is actually now 6ØI1, occupying *1000-*2777.

The record part of the program occupies *1000-*3777 and is 6ØI2. This part of the program sorts out zeros from readings, types

headings, checks whether the display is on or not, sends the program off to compute etc. When the "Record" push button is pressed, various delays are initialized, all 6 A to D converters in the strain gauge equipment are started, and the digital thermometer solenoid energized. After an appropriate time delay an interrupt is issued, and the program identifies the interrupt and goes to the actual "Record" subroutine, which starts at *1055. The push button is inhibited for a period of about 5 seconds to prevent multiple readings if it is dropped, and to ensure that only 1 set of data is taken at a time.

The display program resides in Field 1, and is 61I1, occupying *1000-*7777. Field 2 contains the main computing section, and stores zeros, tables etc. It is 62I1, occupying the whole field.

Computation is based on Ref. 5, so that using the notation and definition given in Appendix 1.

$$Z = K^1_{ZZ}\, S_Z\, (r_Z - \bar{r}_{Zo}) + \ldots. + K^1_{ZL}\, S_L\, (r_L - \bar{r}_{Lo})$$

with similar expressions for M,X,Y,N,L.

$$\eta = \lambda_Z.Z + \lambda_M.M.$$

$$\psi = \lambda_Y.Y + \lambda_N.N$$

$$\phi = \lambda_L.L$$

$$\sin\alpha = \sin\theta\ \cos\eta\ \cos\phi + \cos\theta\ \sin\eta$$

$$\sin\beta = \sin\theta\ \cos\psi\ \sin\phi - \cos\theta\ \sin\psi$$

$$\sin\alpha_1 = \sin\alpha\ \sec\beta$$

$$C_Z = \frac{2.0\ 36\ Z}{0.700\ p\ M_o^2\ S}$$

with similar expressions for C_X, C_Y

$$C_M = \frac{2.036\ M}{0.700\ p\ M_o^2\ Sc}$$

$$C_{X_B} = \frac{(p_B - p)\ S_B}{0.700\ p\ M_o^2\ S}$$

$$C'_X = C_X - C_{X_B}$$

$$C_n - \frac{2.036\ N}{0.7000\ p\ M_o^2\ Sb}$$

and a similar relation for C_ℓ

$$C_L = -C_Z \sec\beta \sqrt{\cos^2\alpha - \sin^2\beta} + C'_X \sin\alpha \sec\beta$$

$$C_D = -C'_X \sqrt{\cos^2\alpha - \sin^2\beta} - C_Y \sin\beta - C_Z \sin\alpha$$

$$C_C = C'_X \tan\beta \sqrt{\cos^2\alpha - \sin^2\beta} - C_Y \cos\beta + C_Z \sin\alpha \tan\beta$$

The arcsine subroutine used is based on :

$$\arcsin X = \frac{\pi}{2} - \sqrt{1 - X}\ \ \Psi(X)$$

where $\Psi(X) = a_0 + a_1 X + a_2 X^2 + a_3 X^3 + a_4 X^4$

where
$a_o = 1.5707,\ 8786$

$a_1 = -\ .2141,\ 2453$

$a_2 = +\ .0846,\ 6649$

$a_3 = -\ .0357,\ 5663$

$a_4 = \ .0086,\ 4884.$

This subroutine gives X to suit the size subroutine used, with X in degrees X100, and shifted left 9.

The double precision square root subroutine is based on :

$$X_{i+1} = 1/2 \quad (X_i + \frac{N}{X_i})$$

It should be noted that the relation used, and the arcsin subroutine, limit the program to $-90° < \theta < +90°$.

4.2 Weight Corrections

A conventional strain gauge balance measures the total load on the model, and the total load consists of the wind load and the

weight of the model. The original program ignored the weight of the model, which meant that operation at fixed model attitude and varying Mach number was necessary, and model weight is then eliminated.

The program modifications are based on equations derived by D.A. Secomb.

The model attitude relative to horizontal is computed from :

$$\theta_a = \theta + \eta \cos\phi - \Psi \sin\phi - \theta_o$$

$$\phi_a = \phi + \phi' - \phi_o$$

where θ and ϕ are the nominal pitch and roll angles recorded for each data point.

θ_o and ϕ_o are the values of the nominal pitch and roll angles for which the model reference system is horizontal, often zero.

η, Ψ and ϕ' are the small angular deflections due to the combined effects of the aerodynamic load and the change in model attitude.

The weight components are given by :

$$Z_W = -W \cos \theta_a \cos \phi_a$$
$$M_W = -W (Z_g \sin \theta_a + X_g \cos \theta_a \cos \phi_a)$$
$$X_W = -W \sin \theta_a$$
$$Y_W = W \cos \theta_a \sin \phi_a$$
$$N_W = W (X_g \cos \theta_a \sin \phi_a + Y_g \sin \theta_a)$$
$$L_W = W (Y_g \cos \theta_a \cos \phi_a - Z_g \cos \theta_a \sin \phi_a).$$

where W is the effective weight of the model, and (X_g, Y_g, Z_g) are the coordinates of the centre of gravity relative to the model reference system, which is the axis system to which the balance matrix and stiffness factors are referred.

These equations are computed in the actual program as :

$$Z_W = (W \cos \theta_a) \cos \theta_a$$
$$M_W = X_W Z_g - Z_W X_g$$
$$X_W = -W \sin \theta_a$$
$$Y_W = (W \cos \theta_a) \sin \phi_a$$

$$N_W = Y_W X_q - X_W Y_q$$
$$L_W = Z_W Y_q - Y_W Z_q.$$

These values are computed for wind-off zeros, and stored, and then computed for each data point, and the increments Z_W (etc.) subtracted from the measured Z (etc.) to give the aerodynamic component.

The validity of the tables may be checked as follows :

(i) Take initial wind off zeros at a given model altitude.

(ii) Set p and H to give a fake Mach number, and this should remain constant.

(iii) Change the model altitude setting and take data points as required, still with wind off.

(iv) Return Mach number to zero, model altitude to its initial value and take final zeros.
The program will now compute coefficients and these should all be zero within the limits of resolution of the whole system. If not, one or more of the values entered in the tables is incorrect and needs modifying.

4.3 Storage Information

4.3.1 Core

	Name		Field	Starting Location
	Tables		2	201
	Raw data	First zero	2	551
		Final zero	2	1001
*		Reading	2	1301
*	Computed data		2	1301
	Mean zero		2	1400
	Wind off weight correction terms		2	1505

* Only one data block is used and computed data is written over the raw data.

4.3.2 Discs

Mode	Data	Zeros Used	Disc Starting Address	Blocks Available (dec.)
Look	Computed	Initial	0010,1003	410
Record	Raw	-	0014,0200	208
	Computed	Initial	0016,0100	208
	Computed	Mean	0016,0100	208
Top of Disc 2 is 0017,7775				

No protection is provided in the program, and no indication that the number of blocks provided has been exceeded. Therefore, it is quite permissible, to use the whole 826 blocks in Look mode, but these data will be written over when Record mode is entered. If a very large number of Record blocks is required, care should be taken that the raw data do not write over the computed data - which will be immediately obvious on the display. Otherwise, appropriate changes to the DISSET subroutine, *2205 Field Ø, may be made to double the Record storage and delete the Look storage. This involves changing the raw data address to the Look disc address, and the computed data address to the original raw data address, which is easier to do than to describe.

In practice, a typical tunnel run uses around 20 - 50 blocks and so very ample storage is already provided.

4.3.3 DEC tape

According to DEC, DEC tape storage is given by :

$$N_B = \frac{212112}{(N_W + 15)} - 2.$$

where N_W is number of words per block and must be divisable by 3.

N_B is number of blocks per reel of DEC tape. Standard block size in this program is 39 words, giving 3926 blocks per reel of DEC tape.

4.3.4 Storage Formats

As a general principle, if raw data are to be stored, it should be stored as soon as possible and as acquired. Therefore, 6END writes the raw data in the format shown on Fig. 5 on DEC tape as soon as possible, and then proceeds to print it out and conduct further manipulations.

Raw data format for the disc storage is shown in Fig. 6 and is now all binary, except for SERIAL number, and the numbers not over written as indicated in Fig. 6.

The format for computed data on both disc and DEC tape, is that shown in Fig. 5.

4.4 Protection and Limitations

1. Strain gauge balance outputs cannot exceed 9999, but in practice, the balance must not be overloaded. Set the 2 high order digits on the thumbwheel switches on the strain gauge equipment for all channels to be used, to a value corresponding to maximum permitted outputs for the balance being used. A beeper will sound and the LED light up on the offending channel if the preset value is reached.

2. Static, total and base pressure are restricted to one word - about 42.00.

3. Reference length $\leq$ 16 inches.

4. $M < 0.10$ is treated as a zero, but in normal operation, $M = 0.000$ is required.

5. For $\theta > 90°$, the computing program will give incorrect answers; raw data is unaffected, but the maximum set table value is presently 99.99°.

6. Roll angle can be up to ° 200.0°.

7. DEC tape must be used for data; format must be 39(10) words per block.

8. For Look mode, 410 points are allowed; in Record mode, 208 points (see 4.1).

9. Do not operate Record push button while display is writing.

10. Do not issue teletype instructions while display is writing or recording of data is proceeding.

5. CONCLUSION

The current version of the program used for six component measurements using strain gauge balances and the DEC 8/I installation in the Transonic Tunnel has been described. Details of the display programs and other changes to early programs are also described, as well as operating details. The program described has been in use for many years, being modified from time to time to suit users recommendations.

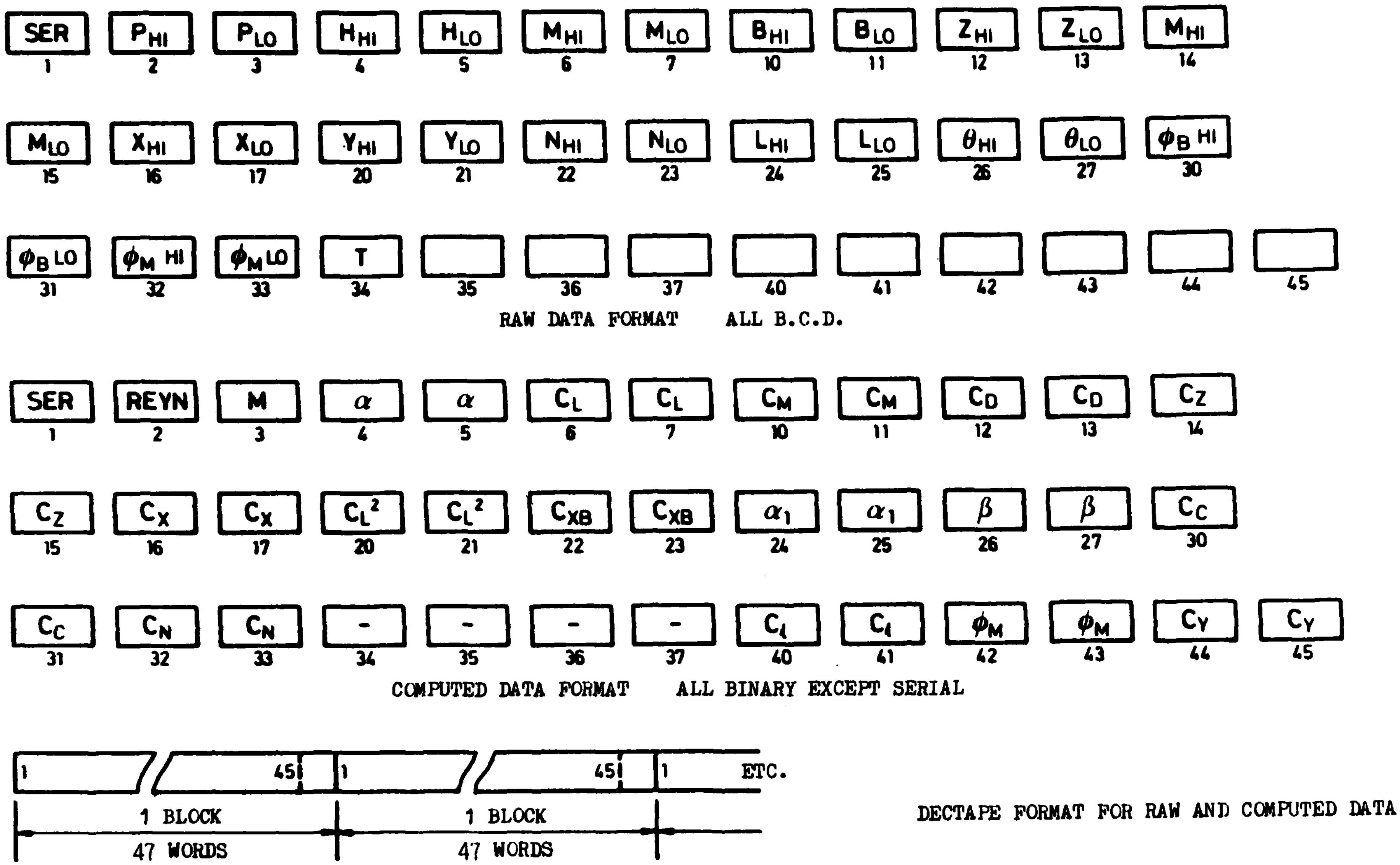
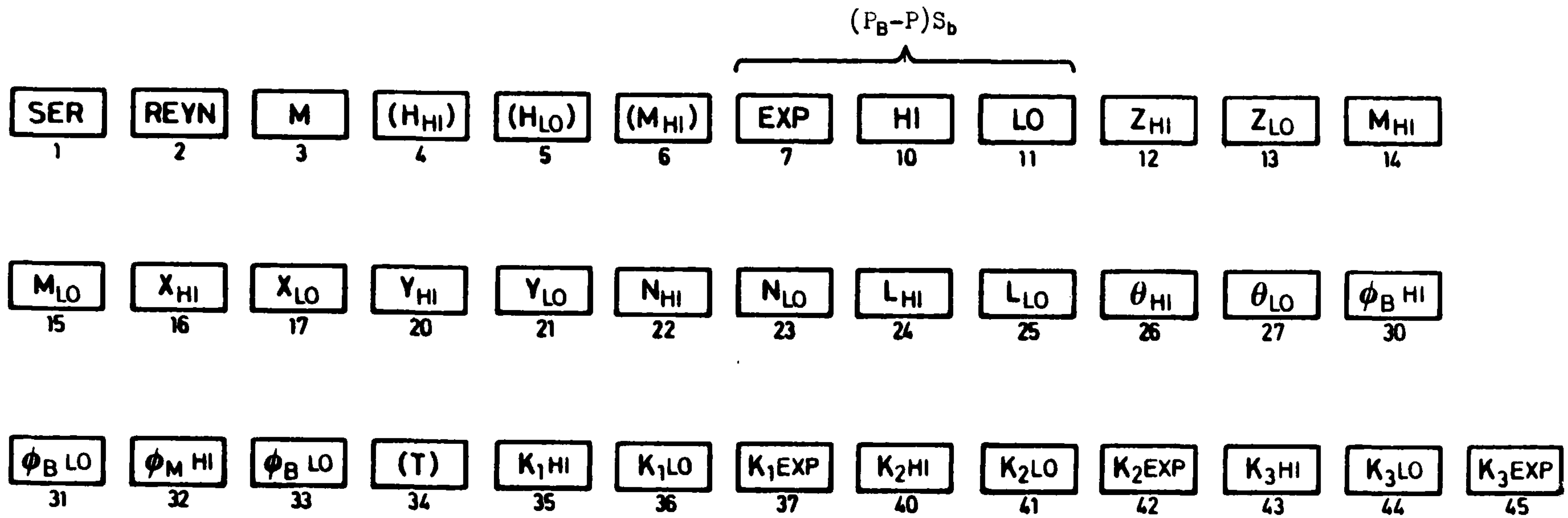


FIG.5 DATA FORMATS.



RAW DATA FORMAT ON DISCS

ALL BINARY EXCEPT SERIAL AND ONES IN BRACKETS

COMPUTED DATA FORMAT ON DISC IS SAME AS DECTAPE

FIG.6 DATA FORMAT.

REFERENCES

1.	Willis, J.B. and Roberts, L.J.	"Programs for the Transonic Wind Tunnel Data Processing Installation Part 4: Six Component Measurements". ARL Aero. Tech. Memo. 264, January 1971.
2.	Pollock, N.	"A-C Excited Self Balancing Equipment for Measuring Strain Gauge Balance Outputs". ARL Aero. Note 341, September 1973.
3.	Willis, J.B. and Roberts, L.J.	"Programs for the Tansonic Wind Tunnel Data Processing Installation Part 1: Minor Programmes and Subroutines". ARL Aero. Tech. Memo. 259, October 1970.
4.	Pollock, N.	"Programs for the Transonic Wind Tunnel Data Processing Installation Part 5: Balance Calibration". ARL Aero. Tech. Memo. 271, August 1971.
5.	Secomb, D.A.	"Notes on the Computer Program for Force Measurements in the Transonic Wind Tunnel". ARL Aero. Tech. Memo. 192, July 1964.

APPENDIX I

NOTATION AND DEFINITION

(See Reference 5)

1.1 Body Axes Force System

Z	Normal Force, positive downwards.	± xxx.xxx lb.
M	Pitching Moment, positive nose-up.	± xxx.xxx lb.in.
X	Axial Force, positive up-wind.	± xxx.xxx lb.
Y	Side Force, positive to starboard.	± xxx.xxx lb.
N	Yawing Moment, positive nose to starboard	± xxx.xxx lb.in.
L	Rolling Moment, positive for drop of starboard wing.	± xxx.xxx lb.in.

1.2 Attitude Angles

θ	Sting root or nominal pitch angle, positive nose-up.	± xx.xx deg
ϕ_B	Sting root or nominal roll angle, positive for drop of starboard wing.	± xxx.x deg.
ϕ_M	Model roll angle, wind-off, positive for drop of starboard wing.	± xxx.x deg.
α	Angle of incidence : i.e. angle between the wind vector and its projection on the chord plane, positive nose-up*.	± xx.xx deg.
β	Angle of sideslip : i.e. angle between the wind vector and its projection on the model plane of symmetry, positive nose to port*.	± xx.xx deg.
α_1	Alternative angle of incidence : i.e. angle between the model axis and the projection of the wind vector on the model plane of symmetry*.	± xx.xx deg.

---

* These definitions apply strictly only in the range -90° to +90°.

η	Angular deflection under load of model, measured in the plane of symmetry, positive nose-up.	± x.xx	deg.
Ψ	Angular deflection under load of model, measured perpendicular to the plane of symmetry, positive nose to starboard.	± x.xx	deg.
ϕ'	Angular deflection under load of model measured around the axis of symmetry, positive for drop of starboard wind.	± x.xx	deg.
ϕ	Model roll angle, wind on, positive for drop of starboard wing.	± xxx.x	deg.

$$(\phi = \phi' + \phi_B)$$

1.3 Sting Balance Stiffness Parameters

λ_Z	deflection per degree by Z load	± .xxxx	deg./lb.
λ_M	deflection per degree by M load	± .xxxx	deg./lb. in.
λ_Y	deflection per degree by Y load	± .xxxx	deg./lb.
λ_N	deflection per degree by N load	± .xxxx	deg./lb. in.
λ_L	deflection per degree by L load	± .xxxx	deg./lb. in.

1.4 Directions of Wind Axes

The lift direction is that perpendicular to the wind vector, in the plane of symmetry, positive upwards for a model in its datum orientation.

The drag direction is parallel with the wind vector, positive downwind.

The cross-wind direction is perpendicular to each of the above directions, and is positive to port for a model in its datum orientation.

1.5 Wind Axes Forces

L	Lift force	± xxx.xxx lb.
D	Drag force	± xxx.xxx lb.
C	Cross-wind force	± xxx.xxx lb.

are the resolutes of the total aerodynamic force in the defined directions.

1.6 Model Geometry

S	Wing area	xxx.xxx $in.^2$
S_B	Base area	xx.xxx $in.^2$
c	Reference chord length	xx.xxx in.
b	Reference span length	xx.xxx in.
ℓ_R	Reference length for Reynolds Number	xx.xxx in.

1.7 Aerodynamic Quantities

p	Reference static pressure.	xx.xx in.Hg.
H	Reference total pressure.	xx.xx in.Hg.
T_o	Total temperature.	xx.x deg.C.
p_B	Model base pressure.	xx.xx in.Hg.
M_o	Mach number based on p and H.	x.xxx
$0.7\, pM_o^2$	Kinetic pressure.	xx.xx in.Hg.
Re	Reynolds number.	xx.xxx million

(The conversion factor from in.Hg. to $lb./in.^2$ is 2.036)

1.8 Body Axes Force Coefficients

C_Z	Normal Force Coefficient.	$\pm$ x.xxxx[2]
C_m	Pitching Moment Coefficient.	$\pm$ x.xxxx
C_X	Axial Force Coefficient.	$\pm$ x.xxxx
C_Y	Side Force Coefficient.	$\pm$ x.xxxx
C_n	Yawing Moment Coefficient.	$\pm$ x.xxxx
C_l	Rolling Moment Coefficient.	$\pm$ x.xxxx
C_{X_B}	Base Force Coefficient.	$\pm$ x.xxxx
C_X'	Corrected axial force coefficient.	$\pm$ x.xxxx

$$C_X' = C_X - C_{X_B}$$

1.9 Wind Axes Force Coefficients

C_L	Lift Coefficient.	$\pm$ x.xxxx
C_D	Drag Coefficient.	$\pm$ x.xxxx
C_C	Cross Wing Force Coefficient	$\pm$ x.xxxx

For all coefficients greater than 9.9999 print out is $\pm$ xx.xxx

1.10 Bridge Scale Readings

r_Z	Reading of Z scale.	$\pm$ xxxx
r_M	Reading of M scale	$\pm$ xxxx
r_X	Reading of X scale	$\pm$ xxxx
r_Y	Reading of Y scale.	$\pm$ xxxx
r_N	Reading of N scale.	$\pm$ xxxx
r_L	Reading of L scale.	$\pm$ xxxx

Suffix $_o$ indicates wind off zero e.g. r_{Z_o}

Bar indicates mean of initial and final values e.g. $\bar{r}_{Z_o}$

1.11 Bridge Sensitivity Factors

S_P	Sensitivity of P channel	± xxx.xxx
	where P may be Z, M, X, Y, N, L.	
	Load for full scale deflection of 9999.	

1.12 Inverse Balance Parameters

K'_{ZZ}, K'_{ZM} etc. (see text).

1.13 Weight Correction Terms

θ_o	Pitch angle when model is horizontal	± xx.xx deg.
ϕ_o	Roll angle when model is horizontal	± xxx.x deg.
W	Effective model weight	± xxx.xxx lb.
X_g	Axial coordinate of C.G.	± xx.xxx in.
Y_g	Lateral coordinate of C.G.	± x.xxx in.
Z_g	Vertical coordinate of C.G.	± x.xxx in.

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16 Abstract

This memorandum describes the current version of the program used for 6 component measurements using strain gauge balances and the PDP8/I installation in the Transonic Wind Tunnel. The program is an updated version of ARL Tech. Memo. A264[1] and has been in use for several years. Changes to the original program include on-line display, model weight correction, and operation with the Pollock strain gauge equipment[2]. Although the 8/I is scheduled for replacement, it may be some time before the changeover to a new installation can occur. Also, some of the program detail may be useful to the new arrangement.

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